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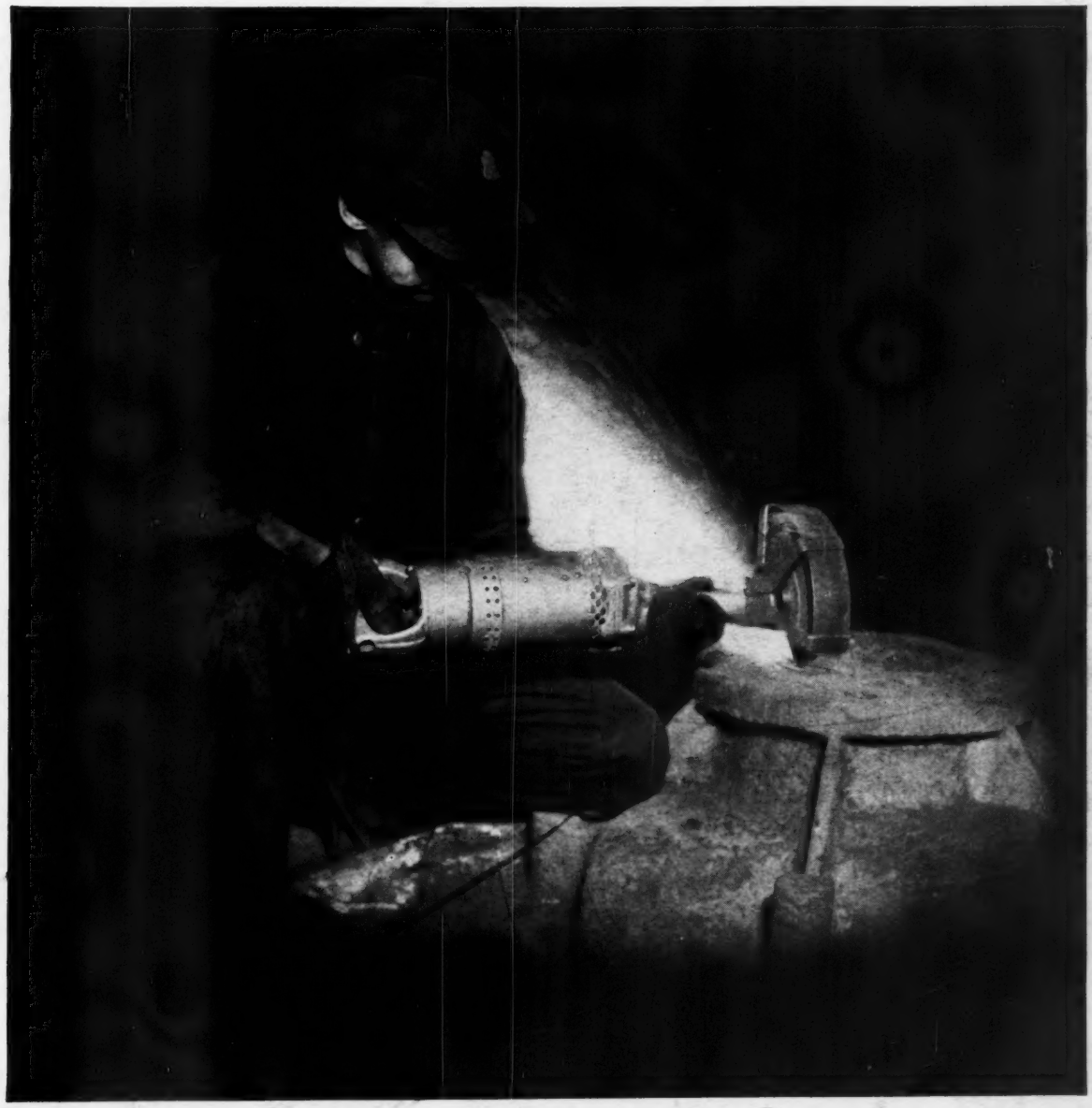

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STACKS

A Modern Aladdin's Lamp

The Heritage of Fabric

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

It isn't codfish—and it isn't cranberries

It's an ultra-short wave radio telephone antenna—before being raised above the dunes of Cape Cod. ¶ For some years, Bell System engineers have been studying ultra-short waves. They have developed automatic transmitters and receivers which may be connected with regular telephone lines at points far from central offices. They hope such radio links will be useful in giving telephone service to points difficult to reach by usual methods. ¶ The installation on Cape Cod—which is now undergoing service tests—is just one more example of Bell System pioneering in the public interest.

Why not telephone home one night each week? Bargain rates after 8:30 P. M.—reverse the charges if your folks agree!

BELL TELEPHONE SYSTEM

THE TECH ENGINEERING NEWS

MAY, 1935
VOLUME XVI
NUMBER 3

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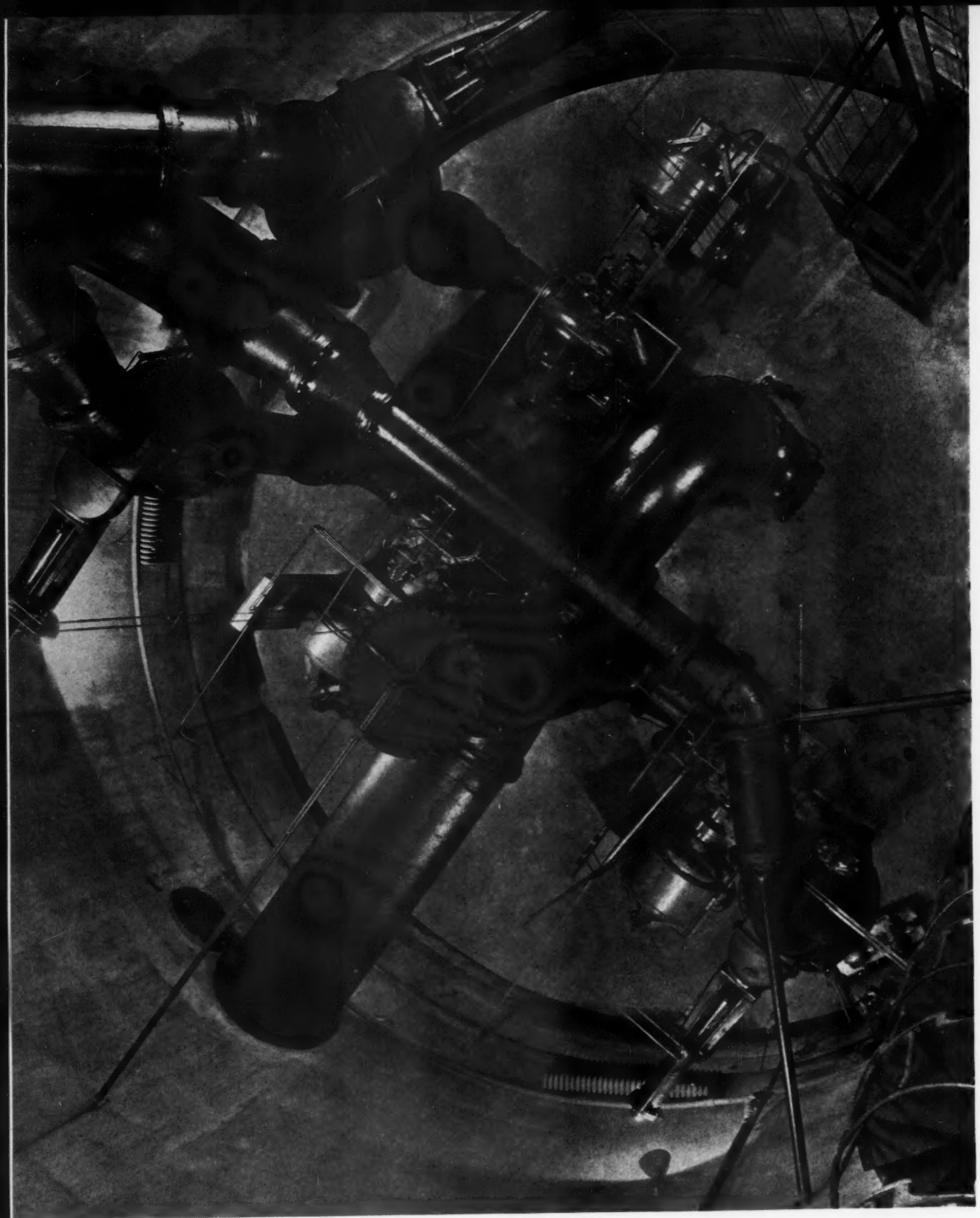


CONDUIT

THE TECH
ENGINEERING NEWS

VOLUME XVI MAY, 1935 NUMBER 3

TECHNOLOGY GRADUATES AS BUSINESS ADMINISTRATORS

By ERWIN H. SCHELL '12
Head of the Department of Business and Engineering Administration
Massachusetts Institute of Technology

DURING the past eighteen years, a procession of somewhat more than twelve hundred graduates in Business and Engineering Administration have entered the industrial field. Throughout this period the department has carried on active correspondence with these men so that today our files contain well over a thousand detailed case histories.

Such letters present a fascinating record of the young men who are devoting themselves to the uses of science in the domain of management. From them, we may project the probable future of the next thousand graduates who will leave the Institute from Course XV.

The chart showing the increasing responsibilities of our graduates tells a significant story. The first year after graduation finds these former students getting at grips with the elementary work of industry. As apprentices, as technicians, as clerks, as salesmen and as skilled and unskilled workmen, they go directly to the front line of activity where the cutting edge of the business is driving its way through the difficulties of manufacture or distribution. As the years progress, these activities change. Follow me through these case histories of our representative students, and you will find that gradually they leave their apprenticeship in these elementary areas for wider opportunities in technical or supervisory fields. Then, as they gain managerial fitness, greater responsibilities are placed upon them until ultimately they realize, as major executives, the primary aim of their Technology training.

If this record of the past is any forecast of the future, it is clear that the young men from Course XV will find it difficult to avoid administrative responsibilities. Indeed, at the close of a fifteen year span, there is but one chance in six that they will hold any other position. And in these later years the distinctions between major and minor executives are of less significance. A position rated in the latter class in a large industry may carry more important duties than that of a major executive in a smaller establishment.

This assurance of future managerial responsibilities has caused me strongly to urge all students in our department to undertake extra-curricular activities of an executive nature. Our former students tell me that this experience has often proved invaluable. Indeed, the extent of such activities is almost universally a subject of inquiry by the companies who wish to employ our graduates.

And if we look at the chart which reflects the financial progress of these men, we can see the premium which industry is willing to pay for the capacity to shoulder executive responsibility. While the opportunities for the functional specialist or the staff advisor have been plentiful, yet the man who has continued to advance in value has been one who could multiply his efforts through others. Executive work demands physical endurance, emotional stability and unusual strength of personality. And such qualities are traditional with Technology men.

The technical training given to Course XV men by the scientific and engineering departments of the Institute is of so fundamental and thorough a nature that we know of no graduate who has found himself incompetent to deal, in an executive capacity, with the technical aspects of his work. Indeed, many of our former students have said that this

"To deal . . . . with the technical aspects of his work"

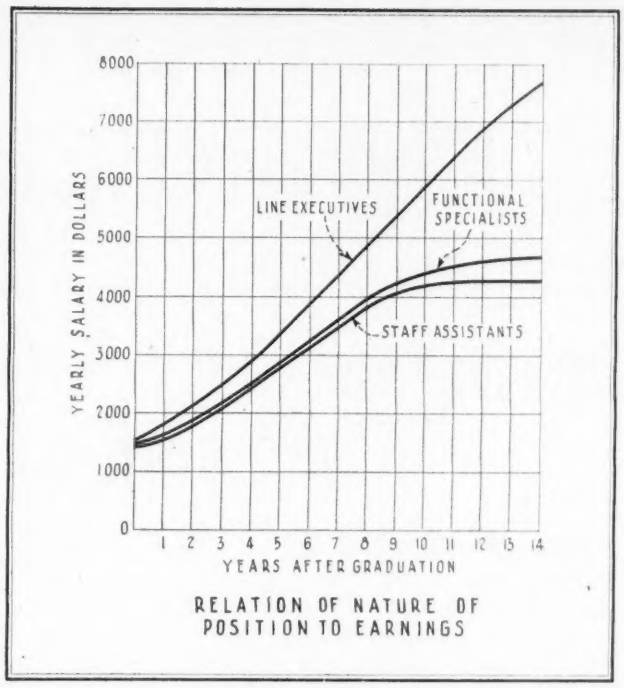
combination of basic professional training in science and engineering with its complement of courses in business administration has provided the surest of foundations for their subsequent progress in business.

I believe that our next thousand graduates will find, as did their predecessors, that greatest opportunity for service will lie in the field of the manufacturing and merchandising of technical products. I think at the moment of a Course XV man who upon graduation undertook an apprenticeship in oil refining. Step by step, he proceeded with the study of the various processes, and although his ultimate position was that of a high executive in the field of distribution, he found that the president relied upon his judgment in all matters where technical and business factors were interrelated.

I think of another graduate who returned to the family business only to find that serious inroads were being made by competitive products. He immediately organized research into the technique of these new processes, developed a small but effective branch of manufacture which today has almost completely absorbed the business. I think of a third graduate who was placed, after a period of training, in charge of a small plant manufacturing a specialty product. He discovered that the special machinery for processing the raw material was quite inadequate from an engineering standpoint. He at once undertook the complete redesign of this equipment, and his efforts resulted in an entirely new installation which effectually solved formidable problems of quality and of operating cost.

If past experience is any gauge, I predict that the majority of these thousand men of the future will ultimately seek opportunities in the medium-sized and small industries. While many of our graduates find early employment in the larger establishments with disassociated plants and centralized administrative offices, the trend over the years shows that the broader administrative responsibilities of the smaller and more homogeneous concerns, outweigh in attractiveness the specialized executive duties offered by the larger units. These men will, I believe, continue to show a predilection for the job which leads to a financial interest in the business and offers an opportunity ultimately to participate in the determination of its major policies.

It is not so easy to forecast those divisions of management through which these young men will make their way to administrative positions. If present trends continue, it is probable that an increased proportion will devote themselves to the initial development and merchandising of manufactured products. There is little question but that those men who have shown proficiency in these areas have



Salaries in many line, staff, and functional positions.

Number Reported	Years After Graduation	Apprentices	Clerical	Engineering Specialists (Designers, Engineers, Draftsmen, Assistants)	Major Executives	Minor Executives	Labor: Skilled	Labor: Unskilled	Salesmen	No Class (Students, Miscellaneous, Unknown)		% Reported
813	1	17.7	11.8	19.4	4.1	11.1	8.1	18	6.8	.05	18.5	85
811	2	9.5	14.2	27.4	6.5	17.8	.38	.27	7.9	9.8		85
743	3	4.0	11.1	25.7	10.5	21.6			10.1			84
677	4	1.9	8.6	22.7	15.0	24.8		.53	11.2	7.9		84
600	5	.55	24.5	18.7	26.0		.04	.02	9.5			83
514	6	.08 .56	18.7	23.8	26.5			.62	10.3	7.8		82
432	7	4.4	18.5	29.2	26.6			.60	8.6			81
338	8	3.9	17.4	33.0	23.2			3.3	8.9	5.3		79
263	9	3.4	15.9	37.6	25.7			3.4	9.9	3.8		78
165	10	3.6	13.3	41.2	23.6			4.9	9.1			78
109	11	10.1		47.7	23.8			3.7	8.3	4.6		77
69	12	8.9		62.3				15.9	4.4	2.9		74
48	13	10.4		62.5				16.7	4.2			73
27	14	3.7	3.7	70.3				14.8	7.4			73

Responsibility trend of Course XV graduates in per cent.

been of greater value to their respective companies than have the men who have concentrated in other fields. It should also be said that the small number of our graduates who have occupied themselves with the financial problems of a business have proved to be of unusual worth.

In general, I believe that the most fruitful opportunities will be those which lie midway between major divisions of responsibility. Receiving as they do, training in the fundamentals of eight specific functions of management, Course XV men are in position to deal intelligently and sympathetically with divisional specialists. Early success in the coordination of dual activities — such as production and marketing, accounting and finance, or production and research—frequently has offered opportunity for more rapid promotion than would be the case if the graduate restricted himself to a single field of effort.

In what industry will these future graduates find their widest opportunity? We all know that promotion is fastest in the expanding industry, and with our past statistics as a guide it would appear that unusual opportunities will be offered in the manufacture of specialties where the management of the company is closely attuned to the changing needs of the market. It is not possible to determine whether chemistry or physics will provide the technical basis of these specialties; there is as much industrial creativeness in one field as in the other. The coming years will beget an entirely new crop of entrepreneurs who will move forward aggressively along untrodden paths. These pioneer undertakings will continue to attract many Course XV men.

Judging from the past, we may be sure that a considerable group of graduates will refuse to accept the prophecy that industry will come to be entirely conducted by gigantic establishments, and they will exercise their conviction by going into business for themselves. In previous years there has been a distinct trend on the part of Course XV men to move from the larger to the medium-sized companies; from the medium-sized companies to the smaller companies; from the smaller companies into their own proprietorships. There is a fascination in owner-management which appeals to the strong personality combining unusual ability with independence of spirit. To be in business for oneself is the ambition of many a Course XV graduate.

Some of these young men will return to the family business. A few years ago a special investigation of this group of graduates yielded unusually interesting information. For example, we found that the large majority of such men entered the family business immediately upon graduation. Furthermore, as years passed very few found these opportunities distasteful or undesirable. In answer to questionnaires, these men told us that not only had their responsibilities been rapidly increased (after ten years eighty-eight per cent were holding major executive positions) but that the depression had in many instances involved them in the entire management of the establishments. The attitude of these graduates has been most gratifying. Instead of viewing wealth as a privilege they have viewed it as a deep responsibility.

You may properly ask if a study of the past indicates the kind of young man who has found greatest satisfaction in these new areas of science in business. I shall be frank in answering this question. The work of administration is to a large extent a problem of co-ordinating widely differing activities. We have found that former students who are happiest in this field are those having a wide range of natural interest. Indeed, it is in response to this fact that the curriculum of undergraduate business subjects tends to broaden in scope, as it progresses.

It is true that we have found a distinct correlation between the ratings which students have received in our course and their later value as measured in terms of income. We have found this correlation to be strongest with marks received in business and economic subjects and in the final thesis. Nevertheless, it should be said that students who show greatest subsequent accomplishment in administration are not always those in the upper scholastic tenth. Instead, the men whose cumulative ratings range between 3.50 and 4.00 and who have interspersed their four years at Technology with a considerable amount of extra-curricular activities seem to be the optimum type for later administrative competence. This fact requires us to admit the presence of qualities other than scholastic standing which make for managerial achievement.

Our study of past graduates has shown a rather striking correlation between undergraduate social activities and vocational opportunities after graduation. We can measure only crudely the social interest of our departmental student body. To do this we have divided the graduates into fraternity and non-fraternity divisions. The record of these two groups in the years following graduation shows clearly that the more socially minded student has a distinct resource of great advantage to him in his later business career. There is no question but that personality is extraordinarily important to the young man who would become the leader of others. I am confident that among the next thousand students who graduate from our department, many will have capitalized to an unusual degree the opportunities which social life at the Institute provides. Administration, to a surprising extent, rests upon mutual confidence and this quality of understanding and trust is frequently as much the result of social as of working relationships.

There is a further trait which I prophesy will be inherent in our future graduates, an attribute which we do not yet know how to measure statistically. I refer to a certain nervous energy, a self-generating vigor which extends its stimulus to others.

The truth is that the administrator is in a distinctly unsheltered position. Every day finds him face to face with inexorable, uncompromising and difficult business situations. His success often hinges upon the quality of his spirit and the degree to which he is stimulated by difficulty and adversity. In times of prosperity his exuberance may take the form of adventure into new products, new processes or new policies. In times of trouble the very presence of obstacles fills him with increased zeal. Mr. Kettering once remarked, "When you get into business, you get into trouble. But fortunately you can pick the kind of trouble you want to get into." There is no question but that the next thousand graduates will get into a good deal of trouble. But most of them will thrive on it, for they will have had preliminary experience with similar difficulties in the classroom during their undergraduate years.

With the rapid spread of collegiate curricula designed to give intensive training in business administration, the competition for managerial posts among college graduates will sharply increase. During the next ten years, administrative responsibilities will be assigned increasingly to men whose previous training has provided them with a detailed yet comprehensive understanding of business fundamentals. With their additional facility in science and engineering we believe that Course XV men will have a competitive advantage of unusual value to their future progress.

Finally, I would prophesy that these young men of the future will continue to be men of character in all that the word implies. Any institution such as Technology inevitably attracts to it high-minded, ambitious students. Young men of today see with clearer eyes than do their parents the forces in life which go to make for happiness or for misery. I am confident that those whose boyhood was lived during the depression years will have a moral fibre, an ethical standard of conduct, a sensitiveness to social implications which will make for exceptionally strong character.

And such men will be needed. Technology has deep responsibility in providing administrative talent for industry, that the products of science and engineering be used to good purpose; that "the industrial pursuits of the age" be furthered.

Machine Design

"The work of administration is . . . . a problem of coordinating widely different activities."

A Modern

ALADDIN'S LAMP

— The Electron Tube

By NORMAN B. KRIM '34
Massachusetts Institute of Technology

WITHIN the last fifteen years both the number of electronic devices in daily use and their industrial importance have increased very rapidly. Electronics as an engineering development is but a child; yet, it has already given birth to new industries and has produced advances in older ones. Aside from the communications and sound picture industries, large investments in electron tubes now exist in the electric power and light field, in metallurgy, in medicine, and in general industrial fields. Electronic devices play such an important role in everyone's life that a working knowledge of electronic nomenclature and some of its main applications should be of use.

Electronic Nomenclature

Most tubes may be identified by several different names. Scientists refer to tubes by their characteristics, such as; the conducting medium, the number of electrodes, the source of electrons, the type of gas, the type of gaseous discharge, the function of the tube in its circuit, and the frequency of operation.*

In practically all vacuum tubes electrons are obtained from the cathode by means of external heating. In gaseous tubes electrons may be obtained in several additional ways. They may be pulled from cold cathodes by very large electric forces found in these discharges; they may come from a mercury pool or a solid cathode, heated by the discharge itself; or they may come from gas molecules affected either by collision or by the heat of the discharge. In general, the term thermionic or hot cathode is only applied to those tubes having externally-heated cathodes. In an electronic photo-cell the electrons are released from the cathode by incident light.

When light is given off by a gaseous device during electrical conduction, the discharge is usually classified as a spark, a glow, or an arc. A spark is a very quick discharge; a glow is a continuous discharge characterized by a voltage drop which is fairly large; an arc is a continuous discharge having a voltage drop of the order of fifteen volts. The term arc is now applied to all forms of discharge which operate with the required low-voltage drop. It is of interest to note that one tube may illustrate all three types of discharge by proper control of the external electrical circuit. In practice, however, the tube gets its name from the type of discharge it is designed for.

Electron tubes used to amplify voltage, current, or power are known as amplifiers. For changing direct into alternating current, vacuum tubes are classified as oscillators or generators, and gaseous tubes are called inverters. When an electronic device is used to change alternating to direct current, it may be termed a rectifier. In communication circuits a rectifier is known as a demodulator or as a detector. A modulator is a tube used to vary the amplitude of a high frequency voltage at a low frequency.

The Thyratron, Grid-Glow tube, and Ignitron are nothing more than gaseous triodes. The Phanotron and the Tungar are gaseous, hot-cathode rectifiers, while the Kenotron is a vacuum, hot-cathode rectifier. The Pliotron is a multi-element vacuum tube.

Communications

Radio is the biggest market for electron tubes. The replacement and new tube business for broadcast receivers alone utilizes millions of units each year. At the present time a single manufacturer offers over seventy different types of receiving tubes. Modern radio apparatus is designed around multi-element vacuum tubes used as amplifiers, modulators, oscillators, detectors, and rectifiers. Gaseous tubes are only occasionally used as rectifiers in receiving installations; they are usually found in transmitting stations in the form of hot-cathode mercury arcs. Gaseous arc tubes are more efficient than vacuum tubes as power rectifiers; in a transmitting station, the power input becomes large enough to make rectifier efficiency an important economic item. High-vacuum radio-frequency amplifiers have already been built in the hundred kilowatt class; a modern radio station recently completed can produce over one thousand kilowatts of radio-frequency power.

Amplifying tubes of the multi-element vacuum type are widely used in telephone repeaters. These devices make long-distance telephony possible. Vacuum tubes are also used as amplifiers, modulators, and demodulators in the telephone and telegraph carrier systems; their application allows a single wire line to carry many different telephone and telegraph messages at the same time.

Research in the field of television has been sufficiently developed to begin preparations to present this long awaited service to the public. Practically all of the technical problems have already been solved; the most important problems still remaining are economic. New vacuum tubes have already been developed for the television projector and camera; similarly, new vacuum tubes are being developed for high-power, ultra-short-wave broadcasting since television programs will be transmitted at these wave lengths. Television receiving circuits for these waves have already been developed, and two methods of relaying television programs have also been recently perfected. Although the quality of the picture which engineers are now able to give the public is of the minimum entertainment value, it is not to be confused with the very poor-quality television systems which were presented to the public several years ago.

Sound Picture Industry

The consumption of electron tubes in the sound picture industry is exceeded only by that of the radio-communications industry. Vacuum tubes are used as amplifiers and photo cells; gaseous arcs of the hot-cathode type serve as rectifiers. To satisfy the needs of the sound picture industry, photo cells and high-power audio amplifying systems were developed. Both of these technical advances opened up smaller commercial fields for electron tubes; photo cells are now being applied to many general industrial problems; high-power acoustical equipment has found a market in the form of public address systems.

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* Author's Note—For a more detailed and comprehensive account of electron tubes the reader is referred to "Electron Tubes in Industry", by Keith Henney.

Electric Power Industry

Large investments have already been made in electronic power rectifiers capable of handling thousands of kilowatts. Electronic installations of this type are the largest which exist. They are rapidly crowding out mechanical rectifiers because of their lower initial cost and higher efficiency. In most of the large installations, arc rectifiers of the mercury-pool type are used because they are able to handle large overloads. The units consist of steel tanks permanently connected to the evacuation pumps; in some cases a control element is added to the rectifier to facilitate voltage regulation and switching. In present-day gaseous tubes the third element is usually called the grid or control element; it is used to control only the starting voltage of the arc, for once the tube is conducting the grid no longer has any effect. In alternating-current work the main arc is extinguished during each cycle, thus giving the grid the ability to stop the discharge completely as in switching or to control the output as in voltage regulation. The grid may control the output by controlling the fraction of each cycle during which the arc is conducting; the power required by the grid circuit is very small. A typical rectifier of this type, rated at three thousand kilowatts, has just been installed in Chicago.

Other power applications of the controlled-arc tube are now being developed. Engineers have already announced a practical system of long-distance direct-current power transmission; this development alone may revolutionize the whole art of power transmission. As inverters, controlled arcs change direct current into any desired frequency of alternating current; the current may then be stepped up or down by conventional transformers; it is then changed back to the direct-current form by controlled rectifiers. Even before a general system of direct-current power transmission is put into effect, the tubes may be used for direct-current transformers and frequency changers. The efficiency of all this apparatus is very high.

Another important power development not yet in practice, is the application of controlled arcs to electric motors. New motor characteristics are obtainable in this manner. Speed and general motor control equipment has also been simplified by the substitution of controlled arcs in place of variable resistances and switches. These new power developments are ready to go into service as soon as industry demands this new equipment.

Electric Light Industry

Carbon and mercury-pool arcs were probably the first of the important electronic tube applications. At present glow tubes of the neon, argon, and mercury-vapor types are widely used for advertising purposes. Mercury-pool arcs are still found in many street-lighting installations; they are also found in factories. Carbon arcs were widely used in the moving picture studios before sound pictures were introduced, but because of their noise they have since been displaced by electron tubes.

Lighting developments are proceeding along three lines. Present advertising signs of the glow type employ cold cathodes; experiments are now being performed to increase the efficiency of these signs by the addition of hot-cathodes. Another development which has already been tested practically is sodium vapor highway lighting. These new lights afford better visibility at the old power input and have already been successfully employed in Europe. An attempt is now being made to produce an electronic light for the home and office because the efficiency of lighting by this means can be made greater than that obtainable with an incandescent lamp. The technical problem not yet solved is the development of a light under which objects will retain their familiar coloring.

An application of the controlled rectifier has been made in the field of stage lighting control. These tubes are used in place of large variable resistances in the saturated-core method of lighting control. The electronic type of control compared to previous types is much more compact and, in practical installations, it has allowed more flexible lighting control. It is now practical to employ automatic control in complex stage lighting.

Metallurgy

In the field of metallurgy, electron tubes have been applied to three important jobs. The spark gap, the controlled arc, and the multi-element vacuum tube are all used in the generation of alternating current for high-frequency induction heating. The high-frequency bombarder is an example of this method of heating. In the manufacture of most electron tubes the electrode metals are freed from absorbed gases by subjecting them to this intense high frequency field.

Electron tubes of the controlled-arc and high-vacuum types have been applied, on a large scale, to welding apparatus. For the large majority of continuous resistance welds, it has been found highly desirable to break the welding current as often as several hundred times per minute. This technique is now used for line and seam welds; in reality, a series of overlapping spot welds is produced. The problem of accurately making and breaking the current several hundred times per minute was never satisfactorily solved by former mechanical systems. Electron tubes provided the ideal solution. Typical circuits employ one or more controlled arc tubes as commutators; these in turn are controlled by high-vacuum tubes which do the timing. The high-current tubes themselves are usually used with saturated-core reactors which are placed in series with the primary of the welding transformer. In this manner the current through the tubes need only be a small fraction of the actual welding current.

X-ray shadowgraphs are now widely used in the examination of welds and castings. Practically every manufacturer of welded pressure vessels in the United States is now equipped with X-ray apparatus. Every weld made in the Boulder Dam, now under construction, is being examined in this manner. An X-ray tube is a hot-cathode, high-vacuum, two-element tube in which very high anode voltages are used. Electrons leaving the cathode are strongly attracted to the anode; when they strike the anode they cause electromagnetic radiation which is shorter than the wavelength of visible light. X-rays affect a photographic plate in the way that light does. If an object is interposed between an X-ray source and a photographic plate, a picture may be obtained of the varying absorption of the X-rays, from point to point, throughout the object. Such a picture, called a shadowgraph, shows clearly the important imperfections which may occur in welds and castings.

Medicine

A large number of electronic tubes are used in medicine for purposes of treatment, surgery, and diagnosis. X-rays, ultra-violet light, and high-frequency power have all been applied to human beings for the cure of disease. The X-ray tube and the electronic cardiograph are valuable aids for discovering diseased conditions.

Ultra-violet light is obtained for medical use from the carbon arc in air and from the mercury-pool arc in a quartz tube. High-frequency power has been used in place of drugs for the purpose of raising the body temperature above normal. Waves of about five meters for this purpose are generated by oscillators of the vacuum type, very similar to those used in ultra-short wave radio systems. Tubes capable of delivering above ten kilowatts at waves as low as

(Continued on Page 58)

Solving

SIMULTANEOUS EQUATIONS

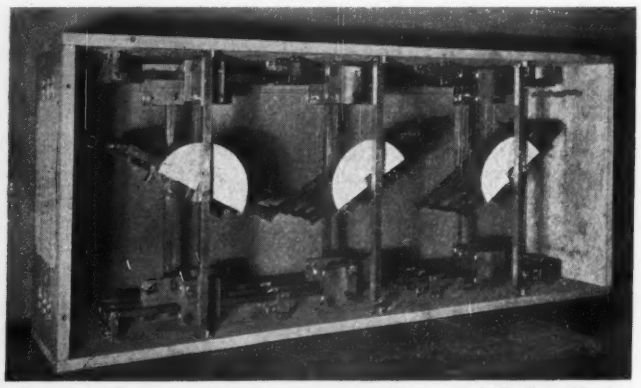
Mechanically

By JOHN B. WILBUR '26
Assistant Professor of Civil Engineering
Massachusetts Institute of Technology

"IN that complex animal the schoolboy, two characteristics are almost universal: a love of mechanics and a strong dislike of work." The foregoing statement, taken from a recent copy of the London Daily Mail, under the heading *"Phipps discusses Mathematics by Machinery,"* continues as follows: "An instrument which panders of both has just been invented at the Massachusetts Institute of Technology (Cambridge, Mass.) . . . . What fascinating possibilities it must suggest to Jones Minor or Smith Tertius. Armed with one of these mechanized cribs, the darkest deviltries of algebra would melt before them, and trigonometry become a mere matter of button-pushing. The ancient enemy, "x", would go in at one end of the machine an unknown quantity, and come out at the other with all its goods in the window. There might, however, be snags attached to the auto-equation solver. 'You appear, Potts, to have solved problem 2 quite admirably in your prep. Perhaps you will be kind enough to step up to the blackboard and show your less enlightened colleagues how you arrived at the right answer.' As long, however, as Potts was careful to avoid any suggestion of infallibility by occasionally doing a sum or two by himself, there should be no likelihood of such embarrassing incidents as the above cropping up."

The upper fourth having been thus encouraged, must set itself for disappointment. For, while the machine referred to is devised for the solution of algebraic equations, its purpose is to aid engineers and research investigators in the analysis of problems made cumbersome by the necessary solution of large numbers of linear simultaneous equations with real coefficients.

The solution of such equations presents no theoretical difficulty. Various methods, some elementary and some involved, are available. But, as the number of unknowns to be obtained simultaneously, and consequently the number of equations to be solved, increases, the labor involved in their solution mounts rapidly.



Technology Review

Experimental model of machine built to solve three simultaneous equations.

Simultaneous equations are frequently encountered in engineering analyses. A specific example of a problem involving their solution is found in the analysis of stresses arising from the action of wind or earthquake forces on tall buildings. A sky-scraper of sixty stories, and with ten rows of columns in a given vertical section, would involve the solution of 660 equations with 660 unknowns, if a so-called "exact" solution is to be made. The time required for the analytical solution of this number of equations would be staggering, and in practice engineers would for this reason undoubtedly resort to approximate methods of analysis. In this particular problem, the recently developed method of moment distribution might be used, which by successive approximations would lead to exact results, but only after considerable expenditure of time and effort. Other examples of problems in Structural Engineering which involve simultaneous equations include primary stress analysis in high masonry dams, suspension bridge towers, airplane frameworks and many other statically indeterminate structures, as well as secondary stress analysis in most types of structures. These examples, drawn from the field of the writer, do not begin to give the proper idea of the diversity of problems which would be aided by the successful development of a machine for the solution of simultaneous equations. Inquiries from research workers in the field of psychology, for example, are indicative of fields of application not suspected when work along this line began at the Institute.

A brief review of the methods available for the solution of the type of equation under consideration would include four main divisions: analytical, graphical, electrical, and mechanical.

It is not the purpose of this article to deal in detail with analytical solutions, but, from the viewpoint of the writer, the analytical method best adapted to the solution of simultaneous equations of the type found in structural engineering, is that of Gauss*. This method enables one to eliminate the unknowns successively in such a way as to maintain the necessary accuracy as the solution progresses. By following this method slide rule computations will generally give excellent results. This method has the further advantage of reducing numerical errors to a minimum by the use of a check column of figures. Some engineers nevertheless prefer the use of determinants for analytical solutions of these equations. While considering analytical solutions, mention should be made of methods which by successive approximations cause the unknowns to converge to their true values. When such a method is available it may be of real value as a labor-saving device.

Graphical solutions of simultaneous equations seem to be so limited in their application as to be of no great value in problems involving a large number of unknowns.

The electrical solution of simultaneous equations may be subdivided into two general fields. The first phase of this

* See Chapter IV of "The Method of Least Squares", by D. P. Bartlett, published by J. P. Shults Co., Boston.

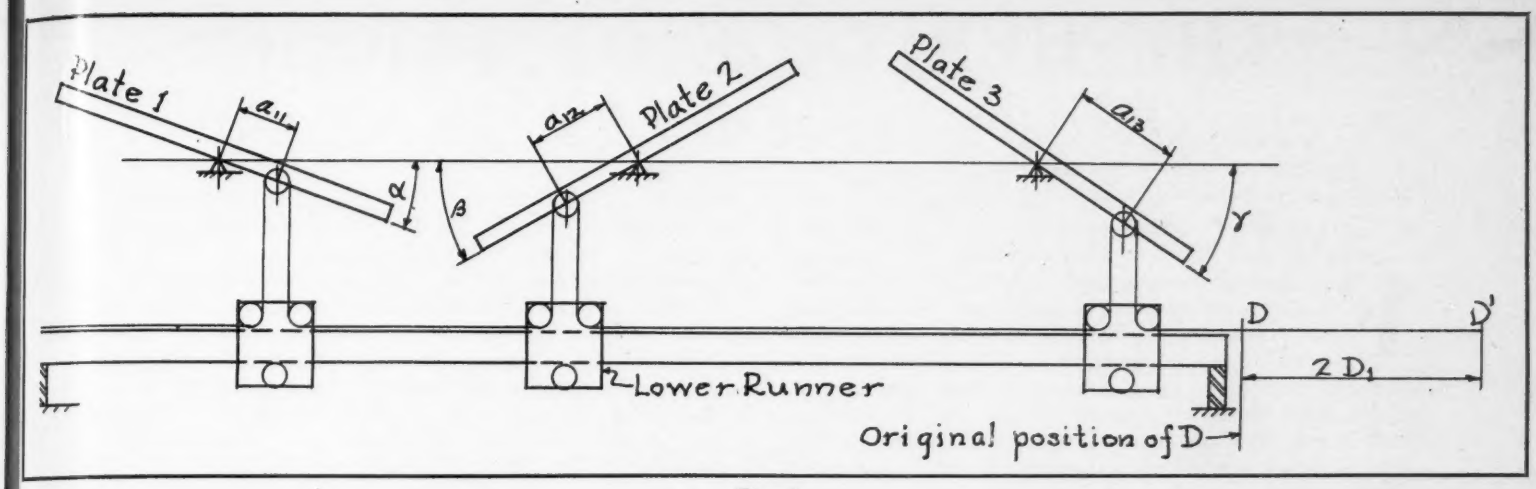


Fig. 1

type of solution utilizes electric analogies by reproducing, on a small scale, the actual problem which is to be solved. The Network Analyzer*, developed at M. I. T. by Dr. Vannevar Bush and Dr. H. L. Hazen of the Institute and O. R. Schurig of the General Electric Co., is of major importance in this field. Developed originally for the solution of transmission line problems, the value of this device is not limited to that field. Professor T. R. Camp, in conjunction with Dr. Hazen, has shown‡ the application of the network analyzer to problems dealing with the flow of water through a network of pipes—problems which in their analytical solution may involve large numbers of simultaneous equations. Dr. Bush has recently extended the use of electric analogies to the solution of statically indeterminate structures†, and by so doing has opened up a field which may develop into an important method of attack for such problems. The major use of the electric analogy approach is, however, limited to problems where a direct analogy is available. Considered purely as a device for the general solution of simultaneous equations, its use is somewhat restricted. The labor involved in devising the proper network to reproduce a given set of equations, together with the fact that the system of coefficients in these equations must satisfy some rather severe conditions in order that the equations themselves may represent a physical network, impose limitations on the adaptability of this method.

The second phase of electrical attack is found in the construction of an electrical device which is built specifically for the general solution of equations of the type under consideration. The recent construction of such a device by the Englishman, R. R. M. Mallock§, presents a real contribution to the problem at hand. Unfortunately, however, in its present state of development his apparatus is expensive.

Mechanical devices for the solution of simultaneous equations seem to divide themselves into two general groups. The first is distinguished by the fact that its action depends upon a continuous motion of the mechanism. In such a machine, the operation takes place over a definite period of time. Such a mechanism has one very definite advantage. The inaccuracies of construction, which must be present in any mechanical device, such as the play of gears on each other, may become negligible when a large number of cycles is considered. Thus, certain types of errors inherent to mechanisms may be made as small as desired by running the device for an extended period of time. This type of machine, which will be referred to as the "kinematic" type, would, however, probably involve greater expense in its construction than would the second type.

The second, or "static" type, as its name implies, undergoes very little motion, or in some cases no theoretical motion. It is not continuous in its operation, for once the coefficients and constants are set on the machine the solution to the equations is immediately available. Such a machine seems to have the advantage of low cost, but is admittedly at a disadvantage as compared to the kinematic type, in that certain types of mechanical errors of construction cannot be minimized in their effect upon results by continuous operation.

In any mechanical approach to the solution of linear simultaneous equations, three major problems present themselves. The first problem to be solved is that of devising a system of setting coefficients to the unknowns. As long as the equations are linear, and with real coefficients, a number of methods readily suggest themselves. Any of the basic simple machines may be utilized. With the lever, for example, the moment of a force acting equals the product of the force and the distance from the point of application of the force to the fulcrum of the lever. This product may be made analogous to the product of a coefficient and an unknown, thus representing one of the terms of the equations to be solved. If the lever arm be taken as the unknown, the coefficient could be set by using the proper weight, or if the weight be taken as analogous to the unknown, the coefficient could be set by varying the position of the weight on the lever. Movements of points on the lever, rather than the effect of the forces acting, might be taken to represent the terms of an equation. The movement of a point on a lever at distance a from the fulcrum equals $a\gamma$, where γ is the angular motion of the lever. Again we have an analogy to a member of a set of linear simultaneous equations, where we may take γ as the unknown and a as the coefficient, which may be readily set on a machine.

The second general problem concerns itself with so arranging the machine that whatever element is to be taken as the unknown shall be common to the various equations involved. Thus, if angular motion or some function of

(Continued on Page 56)

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* "The M. I. T. Network Analyzer", by Dr. H. L. Hazen et al, Contribution from the Department of Electrical Engineering, M. I. T., Serial No. 69, April, 1931.

‡ "Hydraulic Analysis of Water Distribution Systems by Means of an Electric Network Analyzer", by Prof. T. R. Camp and Dr. H. L. Hazen, Publication from the Department of Civil and Sanitary Engineering, M. I. T., Reprint from Journal of the New England Water Works Association, Vol. XLVIII, No. 4, Dec. 1934.

† "Structural Analysis by Electric Circuit Analogies", by Dr. Vannevar Bush, Contribution from the Department of Electrical Engineering, M. I. T., Serial No. 100, October, 1934.

§ R. R. M. Mallock, "An Electrical Calculating Machine," Proc. Royal Soc., 140, No. A841, May 3, 1933, P. 457.

THE HERITAGE OF FABRIC

By E. R. SCHWARZ '23
Associate Professor of Textile Engineering
Massachusetts Institute of Technology

FROM the instant our bodies touch that first intimate and essential article of a baby's apparel immediately following birth, until we rest against the satin linings of our caskets following death, there are few moments of either waking or sleeping hours when we are not in contact with or dependent upon a fabric of some sort. Whether it serves in the form of a parachute to save a flier's life, or whether in the form of clothing it serves simply to minister to our comfort, appearance, or modesty, cloth has become omnipresent and is an important factor in our existence. It has been so for many generations, and we have come to take for granted the presence of fabrics of all sorts, and have ceased to take note of the romance of their early history and their steady development. We fail to realize how closely textiles have been associated with the growth of civilization. We fail to appreciate that today we are benefiting from one of the most ancient arts known to man.

Some cave-man ancestor of ours twisted up the first cord to string a bow, and produced what has been termed the most perfect weapon until the invention of gun powder and the rifled bore. At that moment was given to humanity the means for equality with and eventually supremacy over the beast of the field, the bird of the air, and the fish of the sea. For even today our primitive brethren shoot down the jungle king for his flesh, his sinew and his hide—and use for the purpose an arrow feathered with a quill, and sped upon its way by a fibre bowstring. Even today the workers in one of our vital industries cast their nets and lines into the sea, that the inhabitants of the deep may be tribute to our skill in twisting fibres into strands and weaving and knotting strands into fabrics.

There are today, in distant forests, savage tribes who do not know the use of fire, and who are wholly unacquainted with even the rudiments of agriculture, and yet who have known how to spin and weave for generations. It is a far cry from them to our modern use of textiles for ornament, for dress and for the better construction of many of our mechanical devices. But with them we have a common bond, which also has bridged the centuries of development of the human race. We may not be brothers under the skin, but we are brothers beneath the fabric.

We look upon a work of art and recognize it as a masterpiece. We forget the essential canvas upon which it is painted. We thrill to the music of a Kreisler, and forget the violin string and bow hairs. We spend hours at the movies and think nothing of the fabric curtain which reflects the projected picture and which transmits the sound, in turn to be absorbed by fabric hangings in order that we may best appreciate the latest offering from Hollywood. Tablecloths, napkins, lace curtains and rugs are all commonplace; but all are accepted as signs of civilization. All are fabrics.

Not only are our bodies protected from the elements by ornamental layers of fabric, but our playing fields are similarly guarded from the ravages of the weather. More than half a million yards of canvas goes each year into tarpaulins for the covering of football gridirons, baseball diamonds, and tennis courts. Much of the building construction, which, in the rush of modern living must progress, regardless of heat, cold, sun, rain or snow, is made feasible by canvas coverings ($2,500,000 worth per year) for materials of construction and for building openings alike. Similar fabrics are going into the construction of thousands of miles of roads in this country. One type of road construction calls for a graded gravel surface over which a layer of coarse cotton fabric is spread. Gravel is laid over the fabric and the whole is sprayed with hot tar. The result is a roadway which will not rut nor wash-board. A road which will shed water like a duck's back. A road so simple to repair—after ten years' or more service—that it is only necessary to hitch a tractor to one end of a stretch of fabric, and roll up the surface of the road for any desired distance. Even the new super reinforced concrete speed highways are being made in part of fabric. Above the steel-bonded base of concrete sheets of fabric are used to separate the top layer of cement from the foundation. Minor damage to the road surface can then be repaired easily without disturbing the base.

Again, in this age of speed, the rapid transit tunnel is a necessity in the large city. Its construction is rendered cheaper and safer by a new method of ventilation employing fabric tubes instead of inflexible, heavy and expensive metal pipe. Such tubes are easily bent around corners, will withstand the action of heat and cold, are immune from rust and corrosion, and require no special skill or tools to install. Not only for tunnel construction, but in the continuous service of mining in its various forms, the fabric ventilating tubes are playing a more and more important part. They have, for example, quite changed the methods of mining coal, and made them far more efficient.

And, as far below the ground, so also far above it. The fabric wing and fuselage of the plane above our heads is not new in airplane construction. Even in the so-called "all metal" planes, many yards of fabric and many lengths of cord are used. The gas cells of lighter than air craft are made of fabric. Even the secrets of the stratosphere are likely to be solved by reason of the fabrics used in the construction of the stratosphere balloons.

On the ground we ride on tires reinforced with twisted cotton cords. The windows of our automobiles slide up and down in felt runways. The timing gears are likely to be of laminated fabric. We insulate our houses against the winter cold and the summer heat with felts, and in so doing, we pride ourselves on being modern. But, after all, there is nothing new under the sun. The natives of Tibet and of Mongolia have been insulating their homes this way for more centuries than they can number.

And now, not content with insulating one's house, the latest idea is to heat it with fabrics. Not by burning them but by incorporating in their construction a number of extremely flexible and fine but completely insulated wires instead of yarns. These wires are so connected electrically that when the fabric is plugged into any electrical convenience outlet, it will maintain itself at a temperature substantially higher than that of the room in which it is used. Lace curtains for windows can be made this way, as can upholstery fabrics and carpets. The cloth has been passed by the Underwriters and does not constitute a fire hazard. Still another use is for blankets and for sweaters, vests,

socks, mittens and other articles of wearing apparel. The same construction has been tested for use in airplane wings to prevent or to remove ice formations. In many of the fabrics, the presence of the wires cannot be detected by the uninitiated. The cloth drapes well; feels soft and flexible; and is undamaged by dyeing, finishing or laundering.

While it is well known that the vast majority of books published during the last century or two have been bound in cloth, it may be less well known that even stationery is being made of cotton fabric now-a-days. A number of business concerns are using it and find certain advantages, such as increased resistance to damage through creasing, folding, tearing, and handling. But this is no new idea. In old Peru the financial records of the nation were kept by means of a system of knotted cords. They even had a textile calendar.

Some industrial uses of fabric have caused many a headache to the development engineer. Vacuum cleaner bags are a case in point. Here we must have a container which is light, tough, flexible, inexpensive, porous enough to allow air to pass through it, but so closely woven as to prevent the passage of dirt and dust. The modern housewife, having been made germ conscious by the many sponsors of radio broadcasts who advertise this, that, and the other thing for germ killing, is demanding a cleaner bag which will let the air through, but which will retain not only dust, but the bacteria contained therein.

Since we have mentioned the housewife, a word about another domestic problem recently solved by the textile manufacturer is pertinent. It has long been realized that even the finest silverware, when stored in the usual fashion, becomes dull and tarnished, and sometimes quite black because of certain fumes which reach it. One enterprising textile concern, on the watch for a new use for their fabrics, has devised a method of treating cloth for use in wrapping silver which will prevent the fumes from reaching the metal.

Not even on vacations can textiles be left behind. The United States Government has issued a booklet which lists the necessary and desirable fabrics for vacation use—from "adhesive tape" to "window ventilators" and "wood carriers" — some two hundred and sixty in all. Among the more obvious fabrics are mosquito netting, portable boats and canoes, tents, golf bags, bandages, duffle bags, beach umbrellas and sleeping bags. Our interest is aroused, however, by certain of the items, such as "pork bags", "box kites", "chukkers", "tea bags", and, of all things, a "chaise lounge"! (The latter is stated in the bulletin to be "the last word in relaxation.")

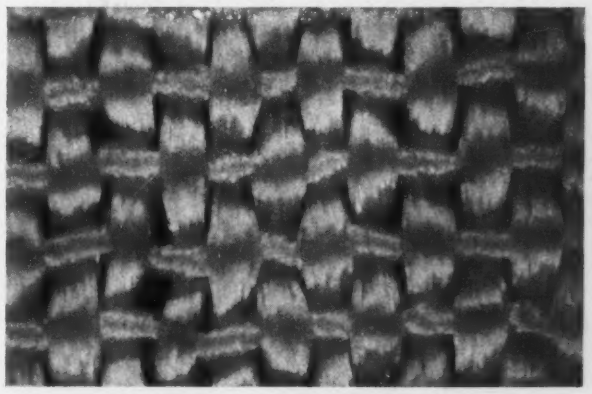
It has been said that nothing takes the place of leather. Fabric, nevertheless, is making a well considered attempt to become a substitute. With the advent of ingenious machinery for chopping fibres into inconceivably short lengths, suedes are being produced for coats and shoes that vie with the best of leathers—except possibly for the smell of the latter. The finely cut (fraction of a millimeter) lengths of rayon are sifted onto a fabric base, coated with latex or cement. The resulting fabric is amazingly satisfactory.

And such success has been achieved in producing cellulosic filaments, that the textile industry has turned for novel and practical fabrics to another product obtained in a similar manner. Liquid rubber is forced through a tiny hole in a spinneret, and coagulated into a slender filament, like a textile fibre, but with the elasticity of rubber. The resulting *Lastex* yarns are woven and knitted into cloth for bandages, for foundation garments, for bathing suits, for something new almost daily. With the present popularity of stream lines in almost everything, the textile manufacturer has adopted this method for aiding the fair sex, and again, textiles have made man master of the sea beast, for whalebone has passed from the picture.

Someone has said that nature moves in a mysterious way her wonders to perform: She gives us a plant whose seeds are embedded in a mass of soft fibre—a fibre which we know as King Cotton. She gives us animals with fleecy coats which can be shorn to furnish our familiar wool. She allows a worm to build itself a house which we proceed to take apart to obtain our lustrous silk. From the leaves of one plant she provides us with manila, while from the stems of others come our old friends flax and jute. And all these are produced in abundance for the taking. We think ourselves intelligent. We mark the new developments in science as a tribute to our brain and skill. But with all our talk of molecules, of atoms, of electrons, of compounds, of isotopes, of colloids, of cosmic rays—with all our test tubes and our laboratories—we have yet to equal nature in producing textile fibres. Man-made rayon is a remarkable thing. But we have not yet duplicated the product of the lowly worm. We cannot yet compete on equal terms with the humble sheep. We must still bow to the earth-bound plant. We can only say of rayon as Shakespeare might have said—"A poor thing, but mine own!"

The trailing and twisting lianas of the jungle may have taught our ancestors in bygone centuries how to spin. But the art of producing a fabric is mankind's achievement alone! It would be hard indeed to find in nature a woven or a knitted fabric. Cloth is one of the few artifacts of which man may well be proud. A fabric lends itself to artistic blending of colors as does a picture. But it does more than this. It affords the same opportunity to the artist as does sculpture:—it allows work in three dimensions. The draping qualities of fabric are unique and have been widely used to beautify both ourselves and our surroundings. Whole schools of art have been based on rendition of fabric draping. This property allows the skillful user to enhance or to conceal the lines of form or figure as he wishes. A fabric is responsive to any mood of the designer, clinging or billowing according to desire.

Fabric has grown up with man. It has borne him company throughout the ages. It has been for him a symbol of power when kings have sat enthroned in royal garments. It has become for him a symbol of justice and of learning when judges have donned their robes and scholars their gowns. It has been for him a symbol of piety when monk and nun have arrayed themselves in cowl and habit. It has ever reflected the spirit of the times—from sack cloth and ashes in seasons of repentance and sorrow to satin and velvet in seasons of prosperity and joy. It has offered him a medium for demonstrating mechanical ingenuity and for expressing his artistic aspirations. Much of the soul of man has gone into his tapestries, his rugs, and his laces. Man's culture is revealed in his fabric!



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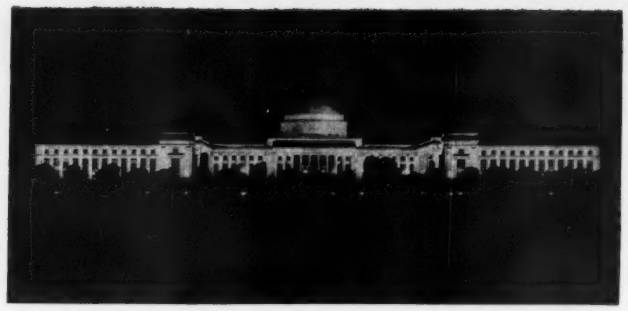

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EDITORIALS

OPEN HOUSE

FROM the student's point of view the various departments of Technology are related to each other like the water-tight bulkheads of a ship. Most of us seem never to get outside the bounds of our own particular courses and we consequently tend to overlook the fact that there are eighteen undergraduate courses and nearly as many departments. Open House Day is the time when the bulkhead doors are opened and it is a splendid opportunity to see how "the other half lives." Everything is "wide open" and no one truly interested in Technology should fail to take advantage of that fact. Every department will put on its most interesting experiments and demonstrations. It is a time to trace to their sources the rumors of new discoveries and developments in other departments than our own.

OLD EXAM FILES

A WELL-KNOWN policy of Tech students in the process of preparing for examinations is to get hold of previous exam papers for use in study. If a sufficient number of these are obtained, it is found that at least seventy-five per cent of the questions to appear on the coming exam have appeared in practically the identical form on the past exams.

This situation of course creates a problem since only a limited number of students have access to old papers. Fraternity files and alumni relatives and friends constitute plentiful sources for some; while for others there seem to be no sources at all. Obviously, it is not fair for some to have these exams while others do not. When placed in competition with the former men, the latter are at a decided disadvantage. Where the latter must co-ordinate theory, method, and calculation, the former may depend entirely on memory.

Solutions for this problem do not seem to be wanting. If there are advantages to be derived from studying past exams in making a comprehensive review for an exam, then would it not be possible for courses to provide old exams for all? If it is also true that a three hour exam actually covers a course so well that it is impossible to write another exam without repeating a question, then it is only fair to everyone that old exams be furnished. It would seem, however, that the whole course is not completely covered in one exam and that questions need not be repeated. Evidently then, in order to test the individual fairly in reference to his standing in the group, either questions must not be duplicated or old papers should be provided for all.

LICENSING ENGINEERS

THE increasing competition in the field of engineering has led many to conclude that the engineers of the country must unite to protect and maintain their status. This idea has found an outlet in a movement, started two decades ago, towards the registration or licensing of engineers by the individual states, and has influenced legislation of this type in twenty-nine states. Before forming any definite opinion, we should do well to consider the opposing views, with particular reference to the effectiveness of state registration of engineers.

The proponents of bills for state licensing believe that the results gained would be analogous to the benefits derived from the laws regulating the professions of law and medicine, the elimination of the incompetent. But the analogy does not exist. The medical profession is highly subdivided and specialized, but all its branches, however divergent, deal with one single subject: health. All special fields of study diverged from one study—the living body. It is quite otherwise with engineering—many professional services and studies of very diverse origin, nature and subject-matter have come to be grouped under the common name—engineering. The name represents a synthesis—not, as in medicine or law, an analysis. Engineering is a convergence—medicine, specialized, represents a divergence.

No single examination, no definable set of standards can be proposed that will justly determine the engineer's right to practice, as can be done in the case of medicine or law: a guidance for engineering cannot be inferred from the success of licensing in medicine.

License in engineering is misleading, because the signature and seal "Licensed Engineer" implies to the layman that the engineer can do anything. An engineer who is competent in machine practice should not atttempt to design a bridge. Yet the incompetent engineer, or the mechanic who can obtain a license, may bolster false claims of competence by means of the title "Licensed Engineer."

TO THE CAUSE OF PEACE

AT a time when the need for cries of "Peace" is greatest there are too few cries of that nature. Indifference to the matter of peace is the attitude of many people. Perhaps the indifference comes from a lingering-on of the medieval fighting spirit, that fighting spirit which is the measure of virility among primitive people. Perhaps an equally important cause of indifference comes from the distaste with which many people view those most actively engaged in carrying out peace programs. Soap-box orators seem to be thought of too frequently in connection with pacifism. It is an unjust association.

Peace is valuable to everyone irrespective of his political creeds or theories of economics. War is quite impartial in its consequences. At most, no more than a small group can profit by war; not even the victor wins anything but social chaos and economic disturbance as was shown by the last war. War need not be considered from a moral or humanitarian point of view. Sheer selfishness shows the undesirability of a process which kills off friends, which affects the individual indirectly but adversely by killing off the best of the potential citizens, and which drains the individual's pocketbook of the last drop of gold. Nor is there any intellectual justification for an event which strengthens the barriers of prejudice.

The demands for peace should consequently come from all classes and types of people. They should come particularly from the people of the highest moral and intellectual calibre since those people can be the most powerful in establishing peace. Peace need not lurk in unfrequented corners; it should stand in full view as something to be endorsed actively by all citizens and especially by the best citizens.

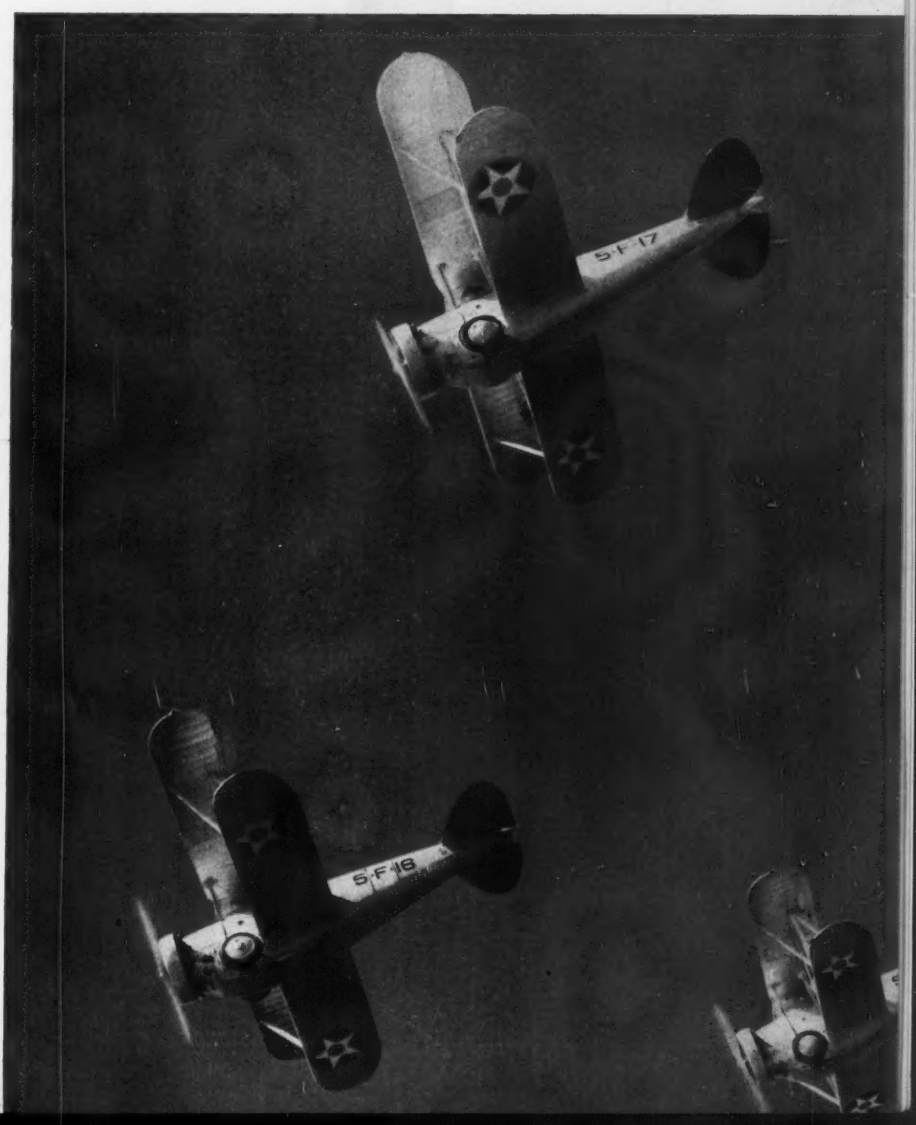
"War is quite impartial in its consequences."

ANNOUNCEMENT

The Managing Board is pleased to announce the following elections to the Business Department of the publication: Norman B. Robbins, '37, to the position of Publicity Manager, Robert L. Johnson, '38, to the position of Assistant Circulation Manager, Murray H. Hayward, '38, to the position of Assistant Treasurer, and Dempster Christenson, '38, and Samuel Hutchins, '38, to the positions of Assistant Advertising Managers.

These promotions are a recognition for service while training for these positions. The Board sincerely hopes that these men will continue to show the same loyalty and effort and advance to Junior Board niches on the masthead of the next volume.

Aero Di



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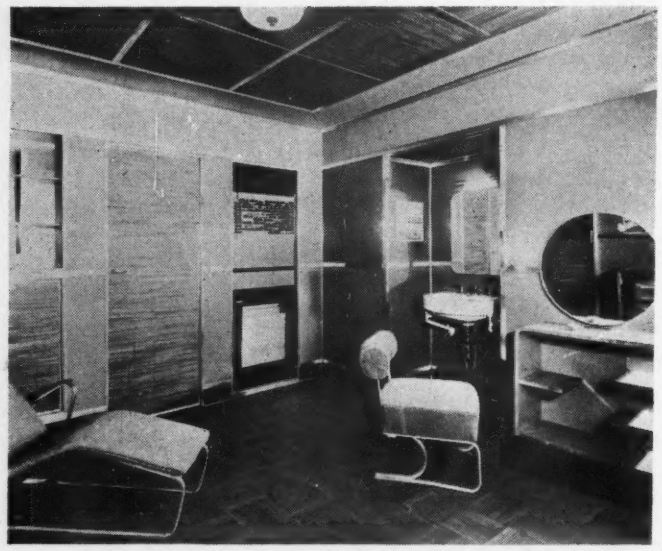

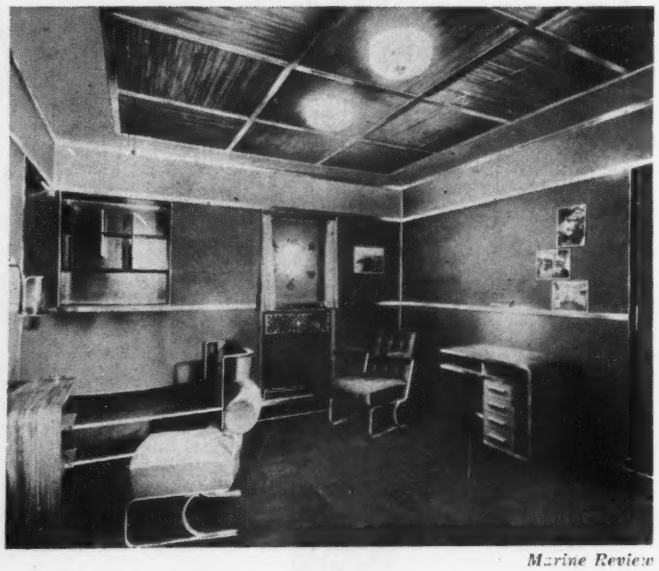

Marine Review

Fireproof cabins exhibited at Milan Fair.

SHIP CABINS

AT the international fair at Milan, Italy, ship companies presented exhibits of staterooms equipped as far as possible to meet the requirements of fireproof construction. In addition to the attainment of fire prevention the accompanying illustrations show the remarkably attractive results achieved.

Incombustibility was sought by making the walls of materials which do not allow the flames to spread to adjoining cabins even if these walls are charred. Heat insulation and noise damping were included. The weight of the partitions was devised such that they were not much heavier than wood or composition construction. The partitions were to be rust-proof in sea air. Space easily accessible had to be arranged for piping. Elasticity of construction had to be provided. It was necessary for proper hygiene to facilitate washing and disinfecting. Finally, the design should be such that it could be fitted on board ship.

The results obtained were very fine. The panels for the walls were made of two hard peraluman alloy sheets 7 millimeters thick, yet with great tensile strength and elongation. Insulating material was glued between these sheets, and on the outside, a sheet of linoleum was applied to replace tapestry or painting of the walls. The flooring and ceiling was similarly formed. The rooms were furnished with attractive modern furniture and, as a result, a completely fireproof, yet a very good looking cabin was the product.

The attention drawn to such fires as the Morro Castle and certain other fires on French liners has made it imperative that steps be taken toward fire prevention. This was, as may be seen, a definite improvement.

NEW LIFE

THE introduction of live steam into hollow rotating drying rolls on paper machines is accomplished by means of an ingenious rotary joint. This has metal-to-metal bearing surfaces shaped like a hollow ball-and-socket joint. As the joint and the rolls showed considerable wear in a short time, replacement was constantly necessary. A maintenance man in one plant conceived the idea of rebuilding the worn out parts. At first only the convex (ball) side of the unit was rebuilt. By means of the oxy-acetylene process it was reclaimed by bronze surfacing, and as it was discovered that with this surface, the whole unit operated more quietly and more smoothly, it was decided that both parts be bronze-surfaced. Thus the bronze took the place of the previous cast iron.

As a result longer effective life of the parts resulted and leakage did not occur so soon. In short, a more superior joint resulted than the original. Therefore, it has now become standard practice to surface each with bronze by the acetylene process when it shows wear. This type of reclamation work is finding widespread use today in many plants. Wear-resisting bronze welding rod is easy to apply and the process should not be overlooked. There are a thousand parts today that could be successfully reclaimed by this method for further service.

Oxy-Acetylene Tips

RESEARCH IN REVIEW

COURSE XII — Geology

THE research in progress in the Geology Department promises many important results. Professor Buerger is using an entirely new apparatus designed at Technology to carry out his X-ray diffraction study of crystals. This apparatus, which enables a small crystal to diffract X-rays to a moving cylindrical film, automatically solves the geometric aspects of crystals. Already very favorable results have been obtained on antimony oxide crystals and a group of minerals like arsenic sulphide; a further application of this new apparatus now in progress, is the study of the different forms of antimony oxide. To facilitate the study of crystals, a determination of the optical properties of organic liquid mixtures is in progress.

Professor Slichter reports preparations for a study of the deep crustal rocks by the analysis of the ground motions set up by the explosions of 100 tons of dynamite in open quarries. At present he is supervising work on a series of portable seismometers so sensitive that they will record slight displacements a hundred miles or more from the explosion. Research done in the preparation of a doctor's thesis has disclosed what appears to be our most reliable quantitative estimate of the viscosity of crustal rocks under very slow deforming forces. Further activities concern a new method for determining the structure of the deep crust. This method employs observations of the ground motion of deep earthquakes and of the internal reflections coming from sharp variations in the deep crust. Thermally drawn convection currents in the deep viscous interior of the earth as well as surface waves from earthquakes are being examined.

Four different projects are being carried on under the direction of Professor Newhouse. These consist of a study for the first time of the distribution of sulphides and two heavy oxides in igneous rocks; a determination of the changes that are found in adjoining rocks when ore is formed; an analysis of the pitchblende silver at Great Bear Lake; and the variation of amounts of a few rare elements dissolved in the different geological formations and ores. Professor Newhouse is also carrying on some work in connection with the National Research Council.

COURSE XVII — Engineering Construction

A STUDY of moisture penetration of brick walls is being made under the direction of Professor Voss and has led into two major hypotheses to date. One of these deals with the constitution of the interfacial "bond layer" which seems to form at the junction of the mortar and brick. A great number of thin sections through this plane have been made and studied under the petrographic microscope. These studies have led to the hypothesis that this interfacial layer, when it existed, was a lime compound. The exact determination of the nature of this compound promises to lead to important data for industry.

The stresses which act to rupture the bond between brick and mortar at the interfacial plane are seriously increased when a differential volume change takes place. By observing the increment of decrease by repeated reversals of wetting and drying, Lieutenant Veale has shown that a relatively stable bond may be produced. This study may provide a new method by which a stronger interfacial bond may be obtained.

COURSE XVI — Aeronautical Engineering

THE investigations of contribution grade which are being carried on by advanced students and the staff in Aeronautical Engineering range from heat convection through boundary layers to the rapidity of muscular response and its relation to airplane control and design, from the measurement of the momentary air reactions on a fluttering wing to the strength testing of loaded structures which carry their load through a stressed metal skin, and from the solution of Laplace's equation with empirical three dimensional boundary conditions to the measurement of the temperature, pressure and humidity of the atmosphere from the ground to the stratosphere.

A typical investigation is that of boundary layers under pressure gradients. The thin skin of fluid—air or water—which is dragged along by the surface of a moving body, called the boundary layer, is the seat of two very important flow phenomena. These two phenomena are the transition between smooth or laminar flow and tumbling or turbulent flow and the separation of the boundary layer from the surface. The first is associated chiefly with the intensity of surface friction while the second depends on pressural drag. In order to make an empirical study of these phenomena at or near the scale and speed of an airplane, the Institute is constructing a small special windtunnel the chief elements of which are a twelve by three foot chromium plated precision metal plate along which the boundary layer will develop for examination and an opposing wall of variable profile whose function is to contract and expand the flow at will for the purpose of creating various pressure gradients along the plate. From velocity traverses made across the boundary layer at a number of positions along the plate and for many air speeds and pressure distributions, empirical parameters will be sought which appear to control the layer transition and separation. This investigation is under the direction of Professor Smith and Dr. Peters.

COURSE III — Ceramics

THE plasticity of clays and other minerals when mixed with water forms the subject of a Doctor's thesis being carried out by E. O. Wilson in the ceramic laboratory. The high plasticity of these clays can be attributed, in part, to their plate-like-structure. For this study an autographic instrument has been constructed to make a high speed stress-strain diagram of a bar of clay in torsion. The stress-strain diagrams of clays are remarkably like those for metals, although, of course, on a much reduced stress scale.

The constitution of the binary series of lead-silica glass is the subject of a Doctor's thesis being performed by G. J. Bair. These glasses are now being tested for index of refraction, coefficient of expansion, and viscosity at various temperatures. In addition X-ray diagrams have been made of thin sections. With this series of data it is hoped to build up a picture of the atomic arrangement in the glassy state.

A start is being made on the study of plastic flow of ceramic bodies at elevated temperatures. It is hoped that this investigation will throw some light on the nature of the glassy bond.

EQUATIONS

(Continued from Page 49)

angular motion is taken as representing the unknown, and all the coefficients to a given unknown are set on a common shaft, the value of the unknown must be common to all equations, and this condition of the equations is satisfied.

The third problem, and perhaps the most difficult one from the practical point of view, is that of summing up the various members of each equation in order that they may be made to equal the constant of the equation. In the lever analogy, if moments are used as a means of representing the products of coefficient and unknowns, the necessary moment for equilibrium might be used as the constant term of the equation, and if the shaft remained in static equilibrium this condition of the equation would be fulfilled. If the movements of points on the lever arm replaces the moment analogy, some means must be devised to sum up the various movements and ensure that their sum equals the desired constant term. In a kinematic machine based upon gears, the differential gear suggests itself as available for this purpose.

The earliest suggestion of a mechanical device for the solution of simultaneous equations which has come to the attention of the writer is that of Lord Kelvin*. His device, based on the previously given classification is of the static type. Coefficients are set as distances on lever arms, and the angular motion of levers represents the unknowns. The unknowns are made common to all equations by so connecting the proper lever arms that they rotate as a unit. The summing of the various movements is accomplished by means of tapes passing over pulleys in such a way that the sum of the movements of all points corresponding to a given equation is measured by the movement of the proper tape end. The device as suggested by Lord Kelvin is open to criticism on several counts: counterweights are necessary to maintain tension in the tapes; the theory upon which the machine is based is not exact, and the overall dimensions of the device are necessarily large in order to minimize the errors due to these approximations. Nevertheless, the fact that the present development at M. I. T. is based upon the same general approach speaks in itself of the high regard in which this early device is held.

Mr. E. L. Rose, formerly on the staff at M. I. T., has suggested a machine of the kinematic type. His mechanism uses the ratio of gears as a means of setting coefficients, with shaft rotations taken as unknowns. Proper shaft rotations are kept common to the various equations by common shafts, and differential gears are used as a means of summation. While attractive for reasons previously given in the discussion of kinematic machines, the expense of variable gear boxes for use in setting coefficients, and of the differential gears which become complicated with a large number of unknowns, discouraged further investigation at the present time along this approach.

Dr. K. W. Miller, Director of the Utilities Research Commission, Chicago, has devised a static machine based upon forces and moments of forces. The moments offer an analogy to the products of coefficients and unknowns. The unknowns are made common to all equations by means of common levers, and the summation of terms is accomplished by means of moments which produce equilibrium. The disadvantage of this approach seems to lie in the fact that friction, which must always be present, enters directly into the equations of moments, and consequently would introduce errors which might be serious.

The development at M. I. T. started early in 1934, and had its original inception in the form of a linkage; the length of the links and the sines of the angles through which the links rotated corresponding to the magnitudes of coefficients and unknowns respectively. Parallelism of certain links ensured that the unknowns were common to the different equations, while movements introduced at the end of a series of links made the sum of the equation terms equal to the constants of the equations.

Further consideration of the problem, aided greatly by suggestions from Dr. Bush, changed the details of the device essentially, although the same basic approach was maintained. The links were replaced by levers upon which coefficients are set by distances measured from the lever fulcrums. The unknowns remained as the sines of the angles through which the levers rotated. Substitution of a tipping slotted plate for a series of levers ensures that the unknowns have common values for all equations. The summation of the movements of points on the plate is accomplished by means of tapes and pulleys as in Lord Kelvin's device.

The principles upon which this machine is based are readily understood by reference to the following three simultaneous equations:

$$a_{11}X_1 + a_{12}X_2 + a_{13}X_3 = D_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$
$$a_{21}X_1 + a_{22}X_2 + a_{23}X_3 = D_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$
$$a_{31}X_1 + a_{32}X_2 + a_{33}X_3 = D_3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

A single equation may be reproduced mechanically as shown in Figure 1. The coefficients a_{11}, a_{12} and a_{13} are set

(Continued on Page 60)

* Lord Kelvin (Sir William Thomson) and P. G. Tait, "Treatise on Natural Philosophy", Vol. 1, Appendix B, C. J. Clay & Sons, London, England, 1890.

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ALADDIN'S LAMP

(Continued from Page 47)

three meters are already commercially available. High-frequency power from vacuum tubes has been used for bloodless surgery, which utilizes an ordinary knife supplied with high-frequency power. The use of this method is still very limited.

The electronic cardiograph is essentially a high-voltage direct-current amplifier with some means for making a continuous record of the output voltage against time. Very minute voltages caused by heart action are found at convenient surfaces of the body. When these voltages are amplified and recorded, specialists can diagnose many heart ailments very accurately.

General Industrial Fields

Thousands of different electron tube applications have been made in general industry. A large number of these are for automatic control and automatic regulation purposes. One of the fundamental electron tube properties, incorporated in many of these devices, is that of amplification or relay action. A single grid-controlled gaseous tube such as the Thyratron may yield a power amplification well over a million.

Grid-controlled gaseous tubes are now replacing electromagnetic relays in some control applications because they are more sensitive and much faster. They are also used as switches and variable resistors.

One particular control combination, known as the light relay, is finding general industrial use on a large scale. It consists of a photo cell and electronic amplifier, usually of the grid-controlled gaseous type. A small change in light intensity operates the electronic relay; in this way, a small change in light intensity may control a very large amount of electrical power.

The light-control relay has been used in production lines for such work as counting and sorting by color. In the latter application, several separate light-control relays are used; each has a different light filter. The relay is used as a continuous inspector of color, reflective power, and capacity in the chemical, paper, and textile industries; for these applications, the relay is arranged to shut down machinery or operate a warning signal, when the product falls below predetermined standards. The light-control relay is now being incorporated in automatic machinery to safeguard humans and to check the alignment of machine parts and materials. Similar units have been used as automatic light switches for airports and school rooms; when natural light falls below a predetermined intensity, artificial illumination is turned on. Other applications include elevator safety control, railway signal control, and traffic light control.

Electronic tubes are now displacing many older industrial methods for the automatic regulation of temperature, humidity, motor speed, voltage, etc. Regulating circuits generally involve some means of obtaining corrective impulses; some means of amplifying these impulses; and some means of making the necessary corrections. Electronic regulating systems are usually much faster and much more sensitive than older methods. In some cases the corrective impulses may be obtained by a light relay operated by a beam of light reflected from an ordinary recording meter; this particular system of automatic regulation is widely used. Principles similar to those used for regulation have been incorporated in control mechanisms designed to follow curves; a practical application, used for some time, controls the output of an unattended hydro-electric plant, from a graphic chart.

The X-ray tube has become a very valuable general industrial tool in the role of super-microscope. X-ray diffraction patterns of many substances can be interpreted to yield pictures of the internal atomic arrangements. By the use of these diffraction patterns, important improvements have been made in many types of industrial materials. The stroboscope and high speed motion picture camera are two additional applications which have been used in industrial development work. The reader is already familiar with the work of Professor Edgerton in this field.

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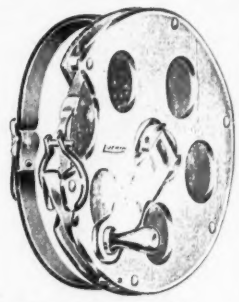

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EQUATIONS

(Continued from Page 56)

on the tipping plates, to the right or left of the plate pivot depending upon the algebraic sign of these quantities. The lower runners, riding on the horizontal rail as shown, ensure that the tapes leading away from the tipping plates will always be vertical.

Now let point D at the free end of the tape be moved to the right or left through distance $2D_1$ to D', as shown in the figure. There are, if only this one equation is considered, an infiinite number of positions which the plates may assume, but for any position we may write:
$2a_{11} \sin\alpha + 2a_{12} \sin\beta + 2a_{13} \sin\gamma = 2D_1$ which is equivalent to equation (1), if $\sin\alpha = x_1$, $\sin\beta = x_2$ and $\sin\gamma = x_3$.

If now three tapes act simultaneously in a similar manner, and on the same plates, each tape represents one equation. If all the coefficients are set and the free end of each tape moved the proper amount, ($2D_1$, $2D_2$ and $2D_3$), there is only one possible angle through which any given plate may turn which will satisfy the three equations. The sines of the angles through which the plates turn are the solution to the equations.

An experimental model was constructed to verify the foregoing theory. It was found that a compensating overhead system of tapes was needed to maintain tension in the tapes at all times. It was further decided that the constants D_1, D_2 and D_3 could be best set on the machine by a fourth tipping plate. The experimental model was built to solve three simultaneous equations and was so successful in its operation as to encourage the construction of a larger machine. An interesting result of experiments conducted on the first machine was the verification of a method of arriving at arbitrary accuracy by successive approximations. Although this model was crude mechanically, two sets of successive corrections gave results to four significant figures.

A machine based upon the same principles, but expanded to handle nine simultaneous equations, was then designed. Through the generosity of Sir Douglas Alexander, President of the Singer Manufacturing Company, a fund was established which makes possible the construction of the new machine.

This construction, which was started last February, will take about a year for completion. In a sense, the new machine may still be considered experimental, particularly with regard to the degree of accuracy which may be obtained. It is hoped that precision sufficient for many types of engineering computations can be obtained from a single set of readings, and it is expected that arbitrary accuracy can be obtained by successive approximations.

A major problem presents itself in minimizing the stretch of the summing tape, so that the geometry of the machine will be maintained. Over a thousand small ball bearing pulleys are to be used to reduce friction and hence reduce the necessary tension in the flexible tapes which are only two thousandths of an inch in thickness. Tolerances in construction ranging from one-thousandth to three ten-thousandths of an inch are numerous in an effort to ensure precision.

The completion of this new machine is expected to accomplish two purposes. First, if it is successful, we will have constructed the first mechanical device for the solution of simultaneous equations which will be of sufficient size to be of use in engineering and research problems. Secondly, the operation of this machine will give us definite clues as to how far this type of mechanism may be expanded in order to handle a larger number of equations.

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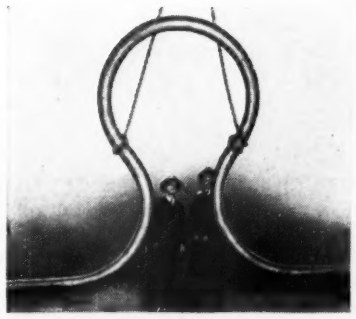
DIVIDEND TOO

Streamlined Piping

Oxy-acetylene welding and cutting add a new note of grace and efficiency in modern piping systems.

By **G. O. CARTER***

NOWADAYS everything is being "streamlined" — airplanes, automobiles, trains, ships, approach their greatest degree of grace and efficiency through this design principle. Usually their streamlining is all on the outside. Piping joined by welding is streamlined both inside and outside.



WELDED ASSEMBLIES such as this loop in a steam line are easily made.

100,000 Miles Installed

Welded joints were first used for river crossings in oil pipe lines. They proved strong and sturdy enough to withstand the shocks of this difficult service. Soon welding came into general use for every joint in the line. Today over 100,000 miles of welded pipe carry oil, gas and gasoline over the country.

The economies which welding brought to the construction and maintenance of pipe lines led to its adoption for power plant and industrial piping. Now it is the first choice of many engineers for all kinds of piping.

Prevents Leakage Loss

Streamlined welded piping has many attractive features besides its smooth lines. Welding is sound, safe, and in the final analysis, the most economical way of putting pipe together.

Welding makes a "jointless" job—insures the owner from future maintenance. Permanence is so positive that in the Cathedral of St. John the Divine in New York, welded piping has been installed in masonry walls fourteen feet thick. In other instances coils of welded piping have been set directly in plaster in the ceilings and walls of beautiful residences. Modern skyscrapers enclose mile upon mile of welded piping. In one building group in the East there are over 85 miles of welded steam piping alone.

Avoids Friction

Pipe joined by welding is smooth inside and outside—truly streamlined. The smooth outside makes insulation less costly and easier to apply. The smooth inside makes friction negligible and reduces power losses. Welded piping is now used for gases and liquids of all sorts and for many solids—requiring pipe of every size and of almost every metal.

Permanent but Flexible

To be a sound investment today, buildings must remain relatively free from maintenance. Piping must be permanent, strong, leakproof and reasonable in cost.

SINUOUS CURVES of welded pipe sweep from floor to floor carrying steam, water, gases and liquids.

Welded piping is permanent. But alterations can be made easily when desired. The oxy-acetylene cutting blowpipe gives the ready means of making an opening. The addition is then tied-in simply by means of welding. This is especially important in the modernization of old buildings.

Installation Facilities Everywhere

The Linde Air Products Company, a Unit of Union Carbide and Carbon Corporation, has pioneered many applications of the oxy-acetylene process in pipe welding. Without cost or obligation to you, it will gladly furnish complete data on welded piping methods. It will make available also such further technical assistance your engineers or construction men may require. Linde Sales Offices are located at Atlanta, Baltimore, Birmingham, Boston, Buffalo, Butte, Chicago, Cleveland, Dallas, Denver, Detroit, El Paso, Houston, Indianapolis, Kansas City, Los Angeles, Memphis, Milwaukee, Minneapolis, New Orleans, New York, Philadelphia, Phoenix, Pittsburgh, Portland, Ore., St. Louis, Salt Lake City, San Francisco, Seattle, Spokane, and Tulsa.

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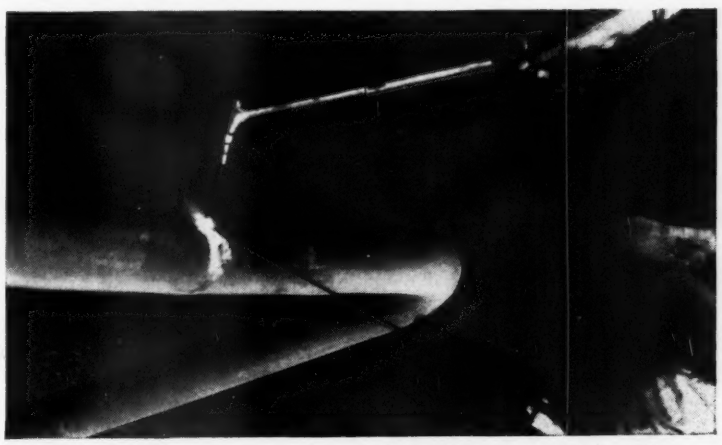

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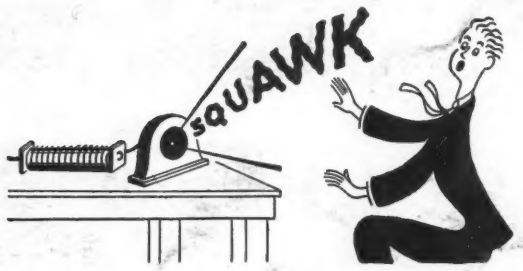
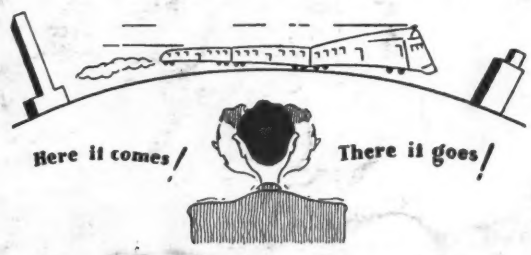
G-E *Campus News*



MAKING FLAWS SQUAWK

A VALVE used in a General Electric refrigerator unit requires a small steel spring, which, during the time that a refrigerator is in operation, is used several hundred times per minute. A small defect, even a microscopic scratch, would be sufficient to cause the spring to fail after a relatively small number of operations. Consequently a fast, certain means of inspection for the steel ribbon of which the springs are made was necessary.

It is generally known that, if a secondary coil is placed around a core of iron and the iron is placed in a magnetic field, there is a definite relation between the chemical and physical properties of the iron and the resultant electrical wave induced in the secondary coil. Using this knowledge as a base, a General Electric laboratory built an inspection device. The spring material is run through a magnetic field, and the induced current is fed through an amplifier to a loudspeaker. A hum peculiar to the magnetic properties of the material sounds in the loudspeaker as long as the quality of the material is uniform. Any flaw, however, changes the magnetic properties, the magnetic field then becomes unbalanced, and the loudspeaker emits a shrill squawk.



STREAMLINE COMMUTING

PORTLAND-BOSTON commuters will shortly receive a taste of real speed. Fairly before they have a chance to swallow their breakfasts, they will be whisked into North Station by the "Flying Yankee." In the morning, the train will streak the 115 miles from Portland, Maine, to Boston in 110 minutes. Then during the day, it will make a round trip to Bangor, Maine, making the 250-mile trip each way in 265 minutes. When the business day closes, it will streak back up Portland way with the commuters it brought down in the morning.

The "Flying Yankee" is a 200-foot articulated train, of lightweight, stainless-steel construction. Its three sections are carried on four trucks. Power originates in a 600-horsepower Diesel engine, directly connected with a General Electric generator. Two General Electric traction motors are mounted in the first truck. An auxiliary generator and the control equipment are also built by General Electric.

HOT DOG

PEG is an elderly English setter, who can trace her family back to some of the very best nobility in her breed. When she was younger, she enjoyed nothing more than romping about in the snow. But in the last few years, American winters, with all their sub-zero weather, have not agreed with her too well.

So last year, her owner, H. C. Ward, U. of Wisconsin, '05, of the General Electric office in Rochester, N. Y., decided to heat her kennel. Quite appropriately, he decided to do the job electrically. He installed a length of G-E soil-heating cable, plugged it into an outlet, and turned on the juice.

He did not stop there, however. Such a fine old dog deserved a polished job. He also installed a G-E thermostat in Peg's quarters to keep the temperature constant through all kinds of weather. Now while other dogs cower in frosty kennels, she disposes herself in luxury. She wags her thanks to General Electric.

96-138DH

GENERAL ELECTRIC

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